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Final Report for the Advanced Outage Control Center Dashboard with Predictive Tools

TCF-16-12126

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1. PROJECT INFORMATION

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1.1 Background

The "Advanced Outage Control Center" (AOCC) pilot project was part of the Light Water Reactor Sustainability (LWRS) program and was a multi-year effort targeted at NPP outage improvement. The primary purpose of this pilot project was to improve management of NPP outages through the development of AOCC features and facilities designed specifically to maximize the usefulness of communication and collaboration technologies for outage coordination and problem resolution activities.

Later stages of the project focused more on tools that utilize technology to improve the outage manager's understanding of the true outage status. The primary tool that resulted from this research was an innovative outage information dashboard with built-in data analysis and predictive capabilities. In its present form, the dashboard specifically takes advantage of visualization techniques that allow users to view and understand the status of the outage at a glance, without the need to drill down to find detail information. The dashboard also incorporates historical performance data to help evaluate current performance. The key innovation in this dashboard concept is not only its ability to avoid the complexity of raw data presentation, but also to predict the completion of the current outage using data analysis of the current schedule and historical performance of the plant.

Through the LWRS program, a relationship between Idaho National Laboratory and Arizona Public Service (APS) was established to investigate the application of specialized techniques to analyze and visualize complex outage information. APS has supported efforts to implement advanced methods to improve the management of outages at the three units of the Palo Verde Nuclear Generating Station (PVNGS). The project has produced the basic principles and methodology for the development of sophisticated outage information analysis and presentation tools.

1.2 Scope and Objective

Outages are a significant cost for nuclear power plants (NPPs) and improvement in outage performance could save NPPs millions of dollars in annual operating costs (Outages cost approximately $2 million/day and last about 30 days; NPPs routinely miss their scheduled end day by several days). Currently NPPs use a wide range of reports to gauge performance, but processing many disparate reports is not only a large cognitive load for the outage crew, but is prone to error and can cause significant delays. This is exacerbated by the fact that NPPs do not have tools to predict outage completion or compare current productivity to past productivity.

The advanced dashboard developed under this project aimed to resolve these challenges by providing more intuitive visualization of abstract NPP outage data and especially by using historical performance data for refueling outages to predict current the probability of completing the current outage with planned resources in the planned timeframes.

The technology employed to improve outage management is a software application that displays an outage dashboard to graphically represent the current status of the refueling outage and provides predictions for completion of bulk work. The software takes previous outage schedule data to compute several productivity metrics; includes algorithms for predicting outage completion time for bulk work; produces a confidence factor for completing on-time; and displays critical path progress, key performance indicators, and management notices. The dashboard is designed to provide a comprehensive overview of current outage performance.

2. PROJECT ACCOMPLISHMENTS

2.1 Current status

The dashboard prototype progressed from requirements analysis, to visualization requirements analysis, concept design, and expansion of functionality and features. This was a rapid development effort to produce a proof-of-concept for the NPP partners. Functionality and user interface are now stable and only enhancement of features and validation of the analytical models remain as the main focus of commercialization. Additional work may also be done to ensure scalability to meet the needs and expectations of the end users (NPP outage managers). The prototype has been demonstrated several times to PVNGS to validate the generic applicability and usability of the software. Specifically, it has been tested for an entire outage to evaluate its robustness and to validate improvements to the user interface.

The dashboard was originally developed with historical outage data from one nuclear facility and was shown to function as intended. The software is intended to be installed in the OCC to be displayed on a large overview screen, or at one or more workstations. The following are the key functions:

1. Upon initial installation, the dashboard has no data and an administrator will load schedules for the first day of an outage, as well as selected historical outage schedules.
2. As the plant moves through an outage, the software reads the outage plan data day by day and plots the NPP's progress to quickly display whether the plant is ahead of or behind schedule.
3. The daily schedule input routine is currently done by hand by the person who administers the program. For commercialization an easy-to-use data input scheme needs to be developed.
4. The dashboard displays selectable overlapping graphs for the baseline schedule, baseline and actual work down percentages, predicted activities to be added per day, actual daily progress and activities completed, actual activities added per day, and the completion confidence factor graph.
5. The dashboard also displays the critical path with indicators for the outage work windows and milestones.
6. Additional detail is also available on nuclear safety, radiological safety, industrial safety, historical outage data, and current activity status.
7. The user can switch between a display of activities and one for man hours.

The images below illustrate the current state of the dashboard:

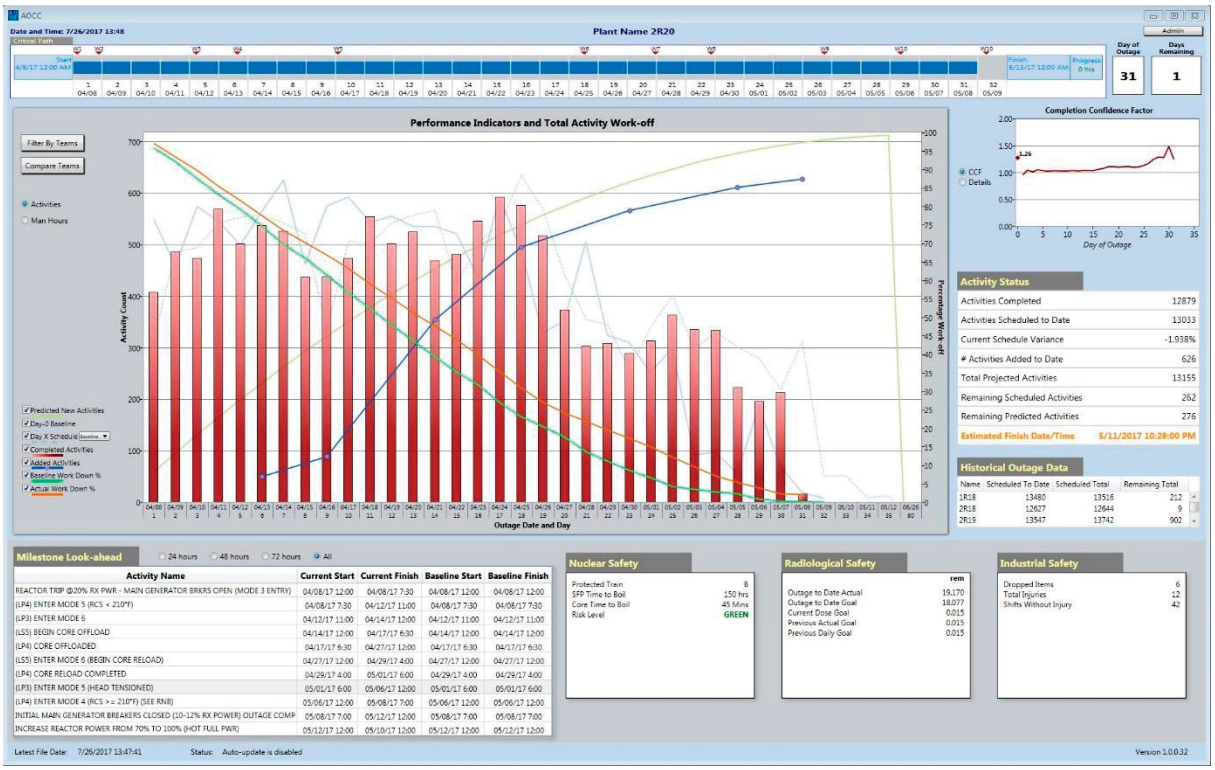

Figure 1: Dashboard showing data for an outage in progress

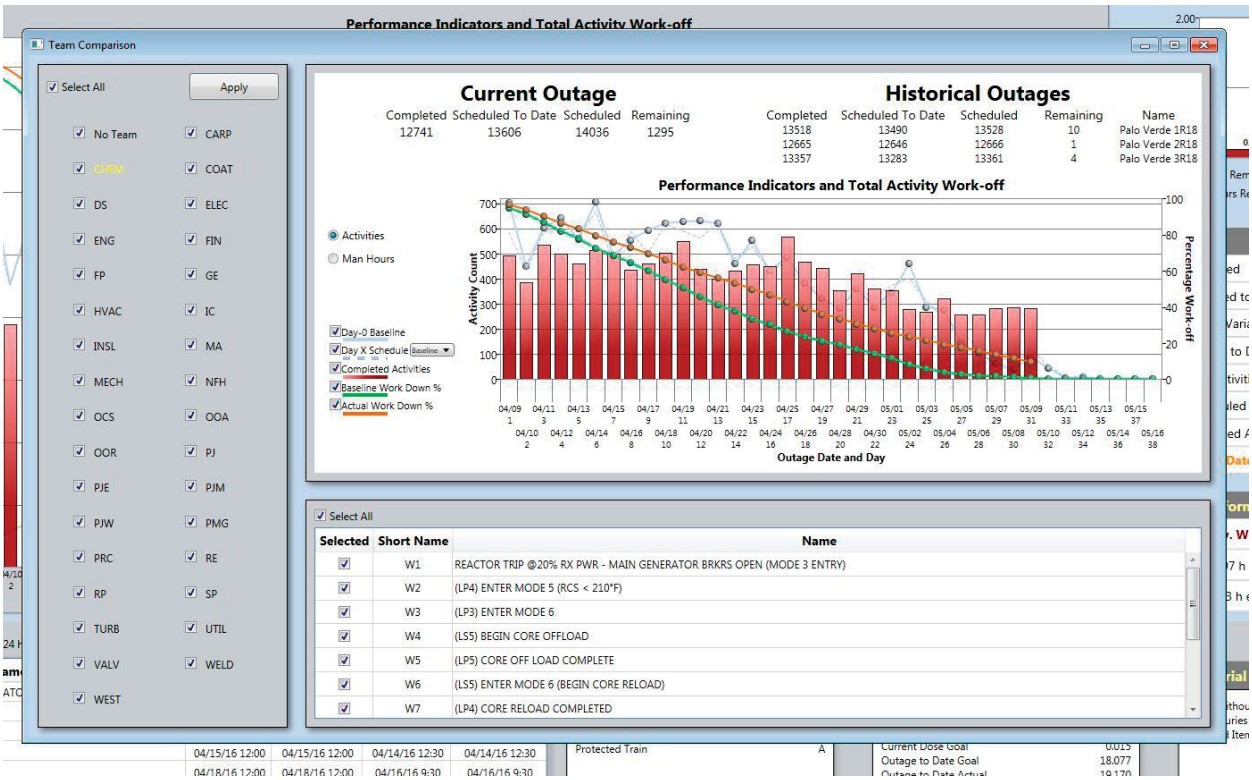

Figure 2: Pop-up window showing team selection options for comparison of manhours

2.2 Application maturity

The prototype was tested by the project team during two PVNGS outages to verify calculations and graph plots. Results from the dashboard were analyzed for accuracy and realism. The PVNGS team continued to work with NPP staff to evaluate the information displayed and continued throughout the project to improve the predictive algorithms and user interface.

Specific updates and improvements were the following:

1. Data input functionality was improved by adding a user interface for importing schedules and also to allow automatic input of schedule files from a network location at a user definable frequency.
2. Improved software features included improvement of the completion confidence factor display, improved team displays, and improved milestone tracking. The admin menu was also improved and significant user-definable features were added.
3. Data Validation – schedule data was collected on 2 outages (3R19 of November 2016, and 2R20 of May 2017) which helped to refine the displays and correct a number of software bugs.
4. Data Connections - the schedule file input was made more flexible to accept different formats of schedule files.
5. On-Line testing – the software was demonstrated at PVNGS as well as at Cooper Station and feedback was solicited from outage managers, which helped to implement further improvements.
6. The work was also presented at the ANS Utility working conference in August 2017.
7. A user's guide was created that can be accessed directly from the software. Additional software documentation was also created to assist in future development by an outside software vendor.

As an additional outcome, the dashboard was designed so that it can scale with work scope and integrate with the NPP's scheduling software. NPPs use a variety of scheduling software applications and have slight variations in their scheduling philosophy. Additional work is needed to ensure the application has universal applicability.

Currently, the dashboard is making predictions exclusively from scheduling data. Through collaboration with industry and vendors, INL will investigate adding additional data streams to the analysis such as clearance order data and radiation control system data. Continuing work on this dashboard will lead to a product that NPPs can utilize to predict a variety of factors during their outages, save them money and resources, and better allocate their human assets.

2.3 Benefit to DOE

All commercial NPPs perform refueling outages, and although some consistently perform well, they all face significant challenges to optimize outage execution due to time, financial and resource constraints. Some utilities have adopted a variety of technologies and tools to support their efforts, none of them has so far succeeded in leveraging historical data to predict outage completion.

The Advanced Outage Information Dashboard developed by the INL team has been demonstrated to several utility outage managers, and the overwhelming response has been they need and want this tool. Although the focus to date has been primarily on PVNGS, the results have shown conclusively that the tool could be used by any commercial NPP. There are currently about 100 commercial NPPs in the US and approximately 442 worldwide with another 66 under construction.

Since this product represents a significant industry innovation, DOE copyright has been obtained (DOE Grant Letter dated July 14, 2017). This has the potential to lead to new business and collaborations far beyond the scope of the few NPPs that have been involved to date.

More specifically, this software application could be used as a stand-alone tool or incorporated into a larger work management software package. In a slightly refined form it could be licensed for inclusion by existing work management software companies such as IBM, Curtiss-Wright, Champs Analytics, Rolls-Royce, ABB, Prometheus, and others. Ideally, it could be offered directly to utilities, and also to existing software companies for integration into their product lines. This application is not intended to replace or compete with existing scheduling software or work management software applications, but to complement them.

2.4 Economic Viability

In its current form, the dashboard prototype is at a Technology Readiness Level 7. The prototype was shown to be near the requirements of a planned operational system. The prototype contains all the functionality that was originally designed, but some of the features will need refinement to improve the user experience and to make provision for site-specific scalability.

As a stand-alone application, a user fee or contract to support customization and integration could be offered. This software application could be ready to deploy within 1 year for initial use using schedule data as an input and then be continuously improved to include more data streams as input. The use of historical outage data to predict current outage performance is an innovative approach that would be a significant improvement over the simple monitoring of percentage deviation from the baseline schedule that is currently used in industry. Several US utilities have expressed interest in using the dashboard, including Southern Company, APS and Nebraska Public Power District. Additionally, several commercial software vendors have expressed interest in licensing the software to help distribute it to utilities.

2.5 Generated Data and Reports

Reports published to date:

1. St. Germain, S., Farris, K., Whaley, A., Medema, H. and Gertman, D. (2014). *Guidelines for Implementation of an Advanced Outage Control Center to Improve Outage Coordination, Problem Resolution, and Outage Risk Management*. (INL/EXT-14-33182). Idaho National Laboratory.
2. St. Germain, S., Farris, R. and Thomas, K. (2015). *Development of Improved Graphical Displays for an Advanced Outage Control Center, Employing Human Factors Principles for Outage Schedule Management.* (INL/EXT-15-36489). Idaho National Laboratory.
3. Hugo, J., St. Germain, S., Farris, R., Thompson, C. and Whitesides, M. (2015). *Design Concepts for an Outage Control Center Information Dashboard*. (INL/EXT-15-37425). Idaho National Laboratory.
4. St. Germain, S. and Hugo, J. (2016). *Development of an Overview Display to Allow Advanced Outage Control Center Management to Quickly Evaluate Outage Status*. (INL/EXT-16-39622). Idaho National Laboratory.

Journal articles:

Hugo, J. and St. Germain, S. (2017). Human Factors in Information Dashboard Design. In: *Proceedings of the 10th International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface (NPIC&HMIT 2017)*. American Nuclear Society. San Francisco, CA.

2.6 Project Status and Summary

The project team's opinion is that there is very little risk in pursuing commercialization of this software application. As indicated before, there are clear indications that industry wants and needs this type of support tool. Any further development of this concept will benefit the nuclear industry and is in-line with the goals of INL. If for any reason the work to fully commercialize the product cannot continue at INL, it is strongly recommended that any remaining work be transferred to a commercial software company for deployment. Several software companies have expressed interest, and it is expected that the dashboard software will be licensed soon.